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IRON AND STEEL

Principles of the Manufacture of Iron and Steel. By Lowthian Bell, F.R.S.

THE work before us, as its title indicates, does not attempt to describe the plant or the manipulation involved in the successful conduct of the several processes pursued in the manufacture of iron, but is confined to a scientific discourse upon the reactions and economics of the production of iron, and more especially upon the question of the economical consumption of fuel in the blast furnace, as based upon the author's long practical experience as a Cleveland ironmaster, fortified by the results of, and deductions drawn from, the numerous and carefully-conducted experiments which he has made upon the chemistry and physics of iron-making. These results have been previously largely published at different periods in the *Transactions* of the Iron and Steel Institute; but, as the author says in his introductory chapter, they "were described in the language of the laboratory," and it is his desire in the present volume to present the general results at which he had "arrived in a more consecutive and less attractive form than that necessarily adopted under such circumstances, and to correct any opinion therein stated which further observation had shown to require modification." The book also contains some valuable considerations of a more commercial character than those usually found in scientific or technical works.

After an introductory chapter, Mr. Bell devotes a section to an interesting historical sketch, arranged in chronological order, of the progress and improvements effected in the iron manufacture, commencing with the primitive forge found in the interior of Africa and closing with the introduction of the basic process for the manufacture of steel. Then follows a chapter upon the direct processes for making malleable iron, in which the economic results of these processes, as against the indirect methods (where the blast and puddling furnaces are conjointly employed), are discussed adversely to the direct processes. Mr. Bell considers that, owing to their simplicity and the partially oxidising tendency of the operations of direct smelting, whereby the phosphorus in the ores is largely left in the slags, these processes have received during the past thirty years more attention than they merit. The author's ideal is a well-appointed blast furnace which expels oxygen from the ore, intercepts the escaping heat, and raises the product to the desired temperature in one apparatus. Owing to an erroneous assumption, viz. that the cost for melting steel in the open hearth furnace is the same whether pig iron and iron ore, or pig iron and scrap, are the materials employed, the author is led to compare somewhat unfairly, on p. 39, the cost for fuel and labour of the product of the Siemens rotary furnace with pig iron produced in the blast furnace. The comparison is made as though the two products were the same, whereas the rotator-blooms are used in the open-hearth steel process in lieu of malleable iron, and not as a substitute for "iron in the form of pig," and hence the comparison should fairly be made as between rotator-balls or blooms and balls or blooms of suitable quality as made by the indirect process of puddling the product of the blast furnace.

Section IV. is devoted to a brief consideration of the preliminary treatment of materials for the blast furnace, such as coking, charcoal-burning, and the calcination of ores; and with Section V., at page 61, the author commences his discussion of blast furnace phenomena, which he continues through Sections VI., VII., VIII., IX., X., and XI., devoting altogether a space of 282 pages to this division of the subject; whilst Chapters XII. and XIII., occupying only forty-eight pages, suffice for the discussion of the phenomena and economic results attending the production of malleable iron from pig iron in low hearths, together with considerations upon the action of the refinery, and of the various forms of puddling furnace, from that of Cort to the Danks, and other mechanical puddling appliances.

Section IX. gives much information of a speculative character, bearing upon the causes of the observed alterations in the relative proportion of carbon, oxygen, and nitrogen to each other in the gases withdrawn at different levels below the furnace throat. A like remark applies to the theories propounded to account for the origin and behaviour of cyanogen compounds in the blast furnace, and likewise to the explanations offered for the appearance of bodies, such as silica, lime, alumina, magnesia, oxide of zinc, and oxide of lead in varying relative proportions in the fume withdrawn with the gases taken at different depths in the furnace.

In Section X. the author maintains the conclusions previously arrived at in his "Chemical Phenomena of the Blast Furnace," viz. that in practice, when smelting Cleveland stone in well-appointed and well-managed blast furnaces of 80 feet in height and from 11,000 to 25,000 cubic feet capacity, driven by a blast heated in pipe-stoves to a temperature of from 500° C. to 600° C., that a ton of pig iron can be produced with the consumption of 20·4 cwt. of coke, which the author calculates is within 1·26 cwt. of the minimum consumption of coke required by theory to smelt a ton of pig iron from the ore in question. He maintains that such furnaces are, and must be as economical in fuel as larger furnaces driven by blast heated in brick stoves to a temperature of 800° C.; but he does not directly venture to dispute the advantage of an increased make per 1000 cubic feet of capacity effected by the larger furnaces and the higher temperatures of blast employed in them.

Mr. Bell dismisses, in the sixty pages of Chapter XIV., the consideration of the manufacture of steel by the Bessemer, the dephosphorisation or basic process, the open-hearth processes, known as the Siemens-Martin, and the ore process. The manufacture of steel in the Pernot furnace, by the cementation and the puddling process, are here also discussed, and in the same chapter are also described the reactions and investigations which resulted in the author's purifying or pig-washing process for the dephosphorisation of pig iron by means of molten oxide of iron added to the charge of phosphoric pig iron contained in a rotating furnace. Further, there is in Chapter XIV. an important sheet of six diagrams, graphically

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representing respectively the order and rate of removal of silicon, phosphorus, and carbon from pig iron in the author's purifying process, in the Bessemer converter, with both acid and basic linings, during the process of mechanical puddling, in the refinery, and during the process of puddling by hand labour.

The thirty-four pages of Section XV. of the volume are devoted to the consideration of facts and figures better calculated to interest the trader and economist, than the manufacturer or scientist; it contains extracts from the statistical returns of the condition of the trade, and make of iron in Great Britain, Germany, France, Belgium, and the United States. Then there follow two sections full of interesting and valuable information upon the labour question, and the effects of free trade principles upon the iron industries. In these sections comparisons are made of the relative cost and efficiency of the British workman as compared with his continental competitor and his American cousin. Commencing with the agricultural labourer, the coal and ironstone miner, the labour employed at the blast furnace, the puddling furnace, in the Bessemer and other methods of steel production, and finally in the engineering and shipbuilding industries, the author shows that throughout, although wages are considerably higher in Great Britain than in any Continental iron-producing district, yet that the English workman, being better fed, does more work per day than his competitor; or, in other words, fewer hands are required in Great Britain than are necessary for the performance of the same work where foreigners are employed. The comparison with the labour of the United States stands, however, differently, the American workman, as a rule (not without exception), receiving a higher rate of wages than the corresponding class in England; such examples being conspicuous amongst the various classes of mechanics, while the individual labourer at the blast furnace is paid at about the same rate in the two countries; but from various causes Mr. Bell states that "the labour on a ton of metal in America amounts to nearly double, and often more than double, its cost in England," and similar results apply to the production of malleable iron by hand-puddling, or to steel ingots from the Bessemer converter.

The last chapter of the volume compares with one another the chief iron-producing countries of the world, their national resources, their competition with Great Britain in English and foreign markets, and the effects of improvements, more especially of the basic process, upon the German steel industries. Mr. Bell concludes the volume with a brief discourse upon the present prospects of the iron trade of the world, and draws the conclusion that the cost of production of pig iron and of steel cannot be materially reduced, except by the reduction of royalties, railway charges, and wages; whilst the puddling furnace is doomed to extinction by its more powerful rivals the Bessemer converter and the open-hearth steel-melting furnace; so that there is little inducement for ironmasters to incur any expense in experiments aiming at the improvement of mechanical puddling appliances. The last-mentioned conclusion is pretty generally accepted, but that the cost of producing pig iron and steel cannot be materially reduced may well be questioned when the immense developments of the last twenty years are considered; and there are many who still hope to see some continuance of this progress, possibly in the direction of a still more economical production of steel from phosphoric and other inferior ores, either by direct processes or by improvements in the existing types of procedure.

The statistical portion of the work is often very indefinite as to the date to which the figures apply to different localities, and the six sections comprised between pp. 61 and 342, treating as they do of the reactions in the blast furnace, the use and theory of the hot-blast, the quantity and quality of fuel required in the blast furnace using air at different temperatures, of the solid products and of the chemical changes as they take place in the blast furnace, on the equivalents of heat evolved by the fuel in the blast furnace, on hydrogen and certain hydrogen compounds in the blast furnace. Each of these sections contains, as might be expected, much valuable information upon the theoretical considerations affecting the combustion of fuel, the effects of increasing the height and capacity of the furnace, and the limits to which the temperature of the blast may be raised with economical results; but the sections might be advantageously condensed, and much repetition avoided, by a more systematic arrangement of the facts and data.

The chemical analyses, results of experiments, the various facts and data, statistical and otherwise, with the discussions thereon as contained in Mr. Bell's volume, make it a most important and invaluable contribution to the literature bearing upon the scientific and economic considerations of our great iron industry, and this notwithstanding that the theoretical deductions which the author propounds may fail to secure universal acceptation. W. H. G.

PHILLIPS'S "MANUAL OF GEOLOGY"

Manual of Geology, Theoretical and Practical. By John Phillips, LL.D., F.R.S. Edited by R. Etheridge, F.R.S., and H. G. Seeley, F.R.S. Pp. 546. (London: Chas. Griffin and Co., 1885.)

THERE are two ends which a Manual of Geology, or for the matter of that of any science, may be intended to compass. It may be meant for beginners, or it may be designed for the use of advanced students. And the ways in which the subject must be handled in order to meet the needs of the two classes are essentially distinct; for it is no less true in intellectual than in physical development that the infant and the adult require different modes of treatment and different kinds of nourishment.

At the very opening of the work before us we find, on a fly-leaf by itself, evidently placed in a conspicuous position for the purpose of calling special attention to it, the aphorism, "Knowledge should be practical from the first," and directions follow as to the way in which the reader can best obtain the specimens by the aid of which alone his knowledge can be rendered practical. Such instructions would be superfluous in the case of advanced students, and we must conclude that the book is intended for beginners. We are warned in the preface that "of things good and beautiful the gods give nothing to men without great toil"; this is a truth which the real teacher never fails to impress on those whom he aspires to guide along the rugged roads that lead to the heights of learning, but at the same time he finds his first and best joy

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